THE ROLE OF CONE BEAM CT IN AIRWAY ANALYSIS

Heidi Kohlfarber, DDS, MS
Diplomate of the ABOMR

Objectives

- 1. Understand the role of cone beam CT in the diagnosis of a limited airway space.
- 2. Develop a working knowledge of the anatomical features which may decrease airway space
- 3. Understand the changes in growth and development which can lead to an increased risk for sleep apnea
Obstructive Sleep Apnea

- Sleep disorder that involves partial to complete obstruction of the airway space in the presence of breathing effort.
- Decrease in airflow by 25-50% (hypopnea) or cessation of airflow for longer than 10 seconds (apnea) resulting in arousal from sleep.
  - Frequency of events is termed apnea/hypopnea index (AHI)
- It is the most common type of sleep-disordered breathing (SDB)
- Prevalence in the US is 2-5% for women and 3-7% for males
  - SBD remains undiagnosed in approximately 93% of affected women and 82% of affected men
  - Prevalence in obese population ranges from 41 – 78%
Obstructive Sleep Apnea

- The severity of sleep apnea is defined as the number of apneas/hypopneas per hour (AHI):
  - 5-15 events per hour = mild
  - 15-30 events per hour = moderate
  - >30 events per hour = severe

- OSA is defined as an AHI of 5 or more + either excessive daytime sleepiness (Epworth sleepiness scale) or at least two of the following:
  - Choking, recurrent awakenings, unrefreshed sleep, daytime fatigue or impaired concentration.

- Polysomnography is the current gold standard.

Physiology of sleep

- Normal adult sleeps approximately 7-8 hrs per night
  - 1/3rd of our lives

- Two phases of sleep
  - Non REM (Rapid eye movement) ~ 75%
  - REM (rapid eye movement) ~ 25%
  - Various cycles through the night (90-120 mins)

- Non REM
- REM
Risk Factors – Non-Mechanical

- Obesity (BMI) – central fat distribution
  - Neck circumference:
    - collar size should not exceed 42cm in males and 37.5cm in females
- Habits – alcohol, smoking, sedatives
- Male sex (male/female 2:1)
- Age
- Postmenopausal state
- Habitual snoring with daytime drowsiness
- Supine sleep position
- Persistent congestion (mouth breathers)
- Hx of medical problems
  - Neurologic syndromes (muscular dystrophies)
  - Stroke
  - Hypothyroidism
  - Acromegaly
  - Environmental factors (allergies, 2nd hand smoke)
  - Syndromes (Down syndrome, Pierre Robin syndrome etc)

Risk Factors - Mechanical

- Facial elongation
- Retrogatnia
- Micrognathia
- Brachycephalic head form
- Hypertrophy of hard/soft tissues
  - tonsils, adenoids, turbinates
- High arched palate
- Retropalatal obstruction
  - Elongated and posteriorly placed palate and uvula
- Retroglossal obstruction
  - Macroglossia and tumors
- Nasal obstruction
  - Polyps, septal deviation, tumors
Consequences of Sleep Apnea

- Coronary artery disease
- Hypertension
- Cardiac arrhythmias
- Type II Diabetes mellitus
- Angina
- Snoring
- Impaired cognitive function
- Hyperactivity/aggression and slow growth in children
- Headaches

- Congestive heart failure
- Memory loss
- Fatigue
- Daytime sleepiness
- Depression
- Mood and anxiety disorders
- Decreased libido
- Traffic accidents (2-7x)
- Occupational injuries (2-3x)

“Don’t Forget what you do, and who you do it for...these are people who you can help”

Dr. Paul Kalanithi
The OSA Work-up

- Systematic Examination:
  - Review the health history – hypertension, congestive heart failure, truncal obesity, neck circumference, hypothyroidism or signs of it.
- Clinical examination: Mallampati score
- Imaging: Airway anatomy, anomalies and pathologies
- Sleep Studies: At home or in the lab (Polysomnography)
- Treatment
- Monitor – follow up sleep study

Types of Imaging

- Dental
  - Panoramic
  - Lateral Cephalometric
  - Cone Beam CT
- Medical
  - Medical CT (MSCT)
  - Magnetic Resonance Imaging (MRI)
### Panoramic

<table>
<thead>
<tr>
<th>Imaging Modalities</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panoramic radiography</td>
<td>• Most common dental radiograph / availability</td>
<td>• Image distortions</td>
</tr>
<tr>
<td></td>
<td>• Low cost</td>
<td>• Superimposition of structures</td>
</tr>
<tr>
<td></td>
<td>• Low radiation dose</td>
<td>• Poor soft tissue detail</td>
</tr>
<tr>
<td></td>
<td>• Broad coverage of facial hard tissues</td>
<td>• Not useful for evaluating airway space</td>
</tr>
<tr>
<td></td>
<td>• High patient tolerance</td>
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</tbody>
</table>

### Lateral Cephalometric

<table>
<thead>
<tr>
<th>Imaging Modalities</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral Cephalometric</td>
<td>• Widely Available</td>
<td>• Performed with patient standing/seated</td>
</tr>
<tr>
<td></td>
<td>• Low cost</td>
<td>• Superimposition of structures</td>
</tr>
<tr>
<td></td>
<td>• Low radiation dose</td>
<td>• Limited soft tissue information</td>
</tr>
<tr>
<td></td>
<td>• Broad coverage of facial hard tissues</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• High patient tolerance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Useful to evaluate skeletal types</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Useful in evaluation of oral appliances and orthognathic surgery</td>
<td></td>
</tr>
</tbody>
</table>
## Cone Beam CT

<table>
<thead>
<tr>
<th>Imaging Modalities</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cone Beam CT (CBCT)</td>
<td>• Available in the dental office</td>
<td>• Poor soft tissue contrast</td>
</tr>
<tr>
<td></td>
<td>• Evaluation of anatomy in three planes</td>
<td>• Ionizing radiation</td>
</tr>
<tr>
<td></td>
<td>• High spatial resolution compared to MSCT</td>
<td>• Beam hardening artifacts</td>
</tr>
<tr>
<td></td>
<td>• Isotropic voxels</td>
<td>• Image noise</td>
</tr>
<tr>
<td></td>
<td>• Allows accurate measurement of cross-sectional area and volume</td>
<td>• Limited scan volume (head and neck only)</td>
</tr>
<tr>
<td></td>
<td>• Lower cost and dose than MSCT</td>
<td>• Patient position – sitting/standing</td>
</tr>
<tr>
<td></td>
<td>• Ideal for airway and bony structures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Metal artifact reduction compared to MSCT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Useful in evaluation of oral appliances and orthognathic surgery</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Patient position – supine</td>
<td></td>
</tr>
</tbody>
</table>

## Medical CT

<table>
<thead>
<tr>
<th>Imaging Modalities</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multislice computed tomography (MSCT)</td>
<td>• Widely available</td>
<td>• High ionizing radiation dose</td>
</tr>
<tr>
<td></td>
<td>• Evaluation of anatomy in three planes</td>
<td>• High cost</td>
</tr>
<tr>
<td></td>
<td>• Provides good temporal and spatial resolution</td>
<td>• Extensive beam hardening artifacts</td>
</tr>
<tr>
<td></td>
<td>• Fast scan time</td>
<td>• Weight limitation</td>
</tr>
<tr>
<td></td>
<td>• Unlimited scan volume</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Ideal for airway and bony structures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Good soft tissue detail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No superimpositions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Patient position – supine (all units)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Lower image noise compared to CBCT</td>
<td></td>
</tr>
</tbody>
</table>
### Magnetic Resonance Imaging

<table>
<thead>
<tr>
<th>Imaging Modalities</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Magnetic resonance imaging (MRI) | • Evaluation of anatomy in three planes
• Superior soft tissue contrast
• No ionizing radiation
• Patient position – supine
• Excellent resolution of the upper airway tissues
• Allows accurate measurement of cross-sectional area and volume
• Dynamic imaging modality | • High cost
• Not always available
• Increased imaging time
• Small confined space (can’t image obese and claustrophobic patients)
• Extensive noise during scanning
• Not for use with some metallic implants, pacemakers and aneurysm clips etc.
• Weight limitation |
What is DICOM?

- Digital Imaging and Communication in Medicine
- ...and Dentistry
- A detailed specification standard for formatting and exchanging images and associated information
CT Image Reconstruction

 Courtesy of Dr. Andre Mol

Number of Projections

 Courtesy of Dr. Andre Mol
Patient Position and Stability

Likelihood of patient movement is inversely related to patient stability... but supine units have a longer scan time thus a greater risk of motion

Other movement reduction strategies
• Head support
• Head strap

Scan time and motion

- Longer times are associated with increased risk of patient motion
- Even the shortest scan times are subject to motion
- The most common cause of patient motion is swallowing
- Head / jaw restraints reduce artifact and the need for retakes
- Seated patients with a chin rest produces the least risk of patient movement
An examples of motion
Reducing the risk of motion: A suggestion

Effect of motion on airway space
Swallowing Artifact

No Motion
Daily Radiation Exposure

- All life on Earth

Natural Sources

- Annual Effective Dose ~3.1mSv
- Several Sources:
  - Cosmic
  - Terrestrial
    - Soil
  - Radon
Natural Sources

- Internal
  - Food!

1050 bananas (potassium 40)
This is known as the banana equivalent dose or BED

Human Sources

- Average Effective Dose 3.1 mSv
- Medical Diagnostics

[Image of human body scan and chart showing medical diagnostics sources]
Background Radiation:
Source contribution to total effective dose
(6.2 mSv) per capita in the US - 2006

<table>
<thead>
<tr>
<th>Source</th>
<th>%</th>
<th>µSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ubiquitous background</td>
<td>50</td>
<td>3100</td>
</tr>
<tr>
<td>Medical</td>
<td>48</td>
<td>2976</td>
</tr>
<tr>
<td>Consumer</td>
<td>2</td>
<td>124</td>
</tr>
</tbody>
</table>

CBCT Dose

- Depends on:
  - Machine
  - Volume
  - Detector type
  - Image resolution (Voxel size)
  - Number of projections
  - Less than conventional CT
Large FOV CBCT scans for all protocols
46 - 1073 µSv
- For standard protocols the mean is 212 µSv

Medium FOV CBCT scans
9 - 560 µSv
- For standard protocols the mean is 177 µSv

Small FOV CBCT scans
5 - 652 µSv
- For standard protocols the mean is 84 µSv

GALILEOS Comfort Plus: Average Adult Comparative Radiation Dosimetry

1. 1 GALILEOS scan
   = 5-6 Panoramic radiographs
   (film/digital)
   or

2. 1/4 of a film based FMX
   or

3. Slightly more than a digital FMX

3. 12 days of background radiation

4. Chance of a birth defect from intra-uterine exposure?
   = ZERO
### Effective Doses from Dental and Maxillofacial X-Ray Techniques and Probability of Excess Fatal Cancer Risk per Million Examinations

<table>
<thead>
<tr>
<th>Technique</th>
<th>Dose microSierves</th>
<th>Fatal CA Risk per Million exams</th>
<th>Background equivalent§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panoramic - indirect digital</td>
<td>14.2</td>
<td>0.8</td>
<td>1.7 days</td>
</tr>
<tr>
<td>Skull/Cephalometric images – indirect digital</td>
<td>5</td>
<td>0.3</td>
<td>17 hours</td>
</tr>
<tr>
<td>FMX (PSP or F-Speed film – Rectangular Collimation)</td>
<td>2</td>
<td>2</td>
<td>6.3 days</td>
</tr>
<tr>
<td>FMX (PSP or F-Speed film – Round Collimation)</td>
<td>35</td>
<td>5</td>
<td>17 hours</td>
</tr>
<tr>
<td>Single PA or Bitewing (PSP or F-Speed film-Rectangular Collimation)</td>
<td>3</td>
<td>0.1</td>
<td>6 hours</td>
</tr>
<tr>
<td>Single PA or Bitewing (PSP or F-Speed film-Round Collimation)</td>
<td>9.5</td>
<td>0.5</td>
<td>1 day</td>
</tr>
<tr>
<td>4 Bitewings (PSP or F-Speed film-Rectangular Collimation)</td>
<td>3</td>
<td>0.3</td>
<td>17 hours</td>
</tr>
<tr>
<td>4 Bitewings (PSP or F-Speed film-Round Collimation)</td>
<td>3</td>
<td>2</td>
<td>4 days</td>
</tr>
<tr>
<td>Cone Beam CT exam (iCAT NG 13x16)</td>
<td>111</td>
<td>6</td>
<td>14 days</td>
</tr>
<tr>
<td>Cone Beam CT exam (NewTom Vgi – 12x15)</td>
<td>108</td>
<td>6</td>
<td>13 days</td>
</tr>
<tr>
<td>Cone Beam CT exam (Sirona GALILEOS – comfort plus – 15x15)</td>
<td>106</td>
<td>6</td>
<td>13 days</td>
</tr>
<tr>
<td>Medical CT Mandible/Mandible – Skull*</td>
<td>2080</td>
<td>134</td>
<td>256 days</td>
</tr>
<tr>
<td>Comparison with Siemens lunar dual (Multi-Bone 3)</td>
<td>186</td>
<td>48</td>
<td>80 days</td>
</tr>
<tr>
<td>Comparison with Siemens 3D mobile dual (Multi-Bone 3)</td>
<td>504</td>
<td>29</td>
<td>45</td>
</tr>
</tbody>
</table>

*Courtesy of Dr. John Ludlow

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### Stochastic vs Deterministic Effects

#### Stochastic effects
- Effects where the **risk** is *proportional* to the dose
- Implies that there is no threshold
- E.g. cancer, mutations (genetic effects)
- Severity of the effect is independent of the dose

#### Deterministic effects
- Effects where the **severity** is *proportional* to the dose
- Implies a threshold
- E.g. sunburn, *in-utero* birth defects, cataracts, radiation burns
Most diagnostic procedures expose the embryo to less than 50 mSv.\(^1\)

This level of radiation exposure will not increase reproductive risks (either birth defects or miscarriage).

According to published information, the reported dose of radiation to result in an increased incidence of birth defects or miscarriage is above 200 mSv.

Note in dentistry we measure dose in *microsieverts*.

- Robert Brent, MD, PhD

https://hps.org/hspublications/articles/pregnancyandradiationexposureinfosheet.html

The uterine doses from naturally occurring background radiation during the 9 months of pregnancy can be expected to be about 75 times that of a film based full mouth series of dental radiographs.

ADA/FDA Selection Criteria Report
Radiation Protection

• Principles
  • Dose Justification
  • Patient Selection
  • ALARA
    • As Low As Reasonably Achievable

Radiation Protection

• Principles
  • ALADA
    • As Low As Diagnostically Acceptable
Poor Image Quality: Underexposed

Comparable Risk Table
One in a Million Risk of Dying

<table>
<thead>
<tr>
<th>RISK</th>
<th>NATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existence</td>
<td></td>
</tr>
<tr>
<td>20 Minutes</td>
<td>Male, aged 60, Cancer</td>
</tr>
<tr>
<td>2 Days</td>
<td>In New York, Air Pollution</td>
</tr>
<tr>
<td>2 Months</td>
<td>In Denver, Cosmic Radiation</td>
</tr>
<tr>
<td>2 Months</td>
<td>In stone building, Natural Radioactivity</td>
</tr>
<tr>
<td>1 Year</td>
<td>Miami water, Carcinogens</td>
</tr>
<tr>
<td>10 Years</td>
<td>Near PVC Plant, Carcinogens</td>
</tr>
<tr>
<td>Travel</td>
<td></td>
</tr>
<tr>
<td>6 Minutes</td>
<td>Canoe, Accident</td>
</tr>
<tr>
<td>10 Miles</td>
<td>Bicycle, Accident</td>
</tr>
<tr>
<td>300 Miles</td>
<td>Car, Accident</td>
</tr>
<tr>
<td>1000 Miles</td>
<td>Airline, Accident</td>
</tr>
<tr>
<td>6000 Miles</td>
<td>Airline, Cosmic Radiation</td>
</tr>
<tr>
<td>Work</td>
<td></td>
</tr>
<tr>
<td>1 Hour</td>
<td>Coal Mine, Black Lung</td>
</tr>
<tr>
<td>3 Hours</td>
<td>Coal Mine, Accident</td>
</tr>
<tr>
<td>10 Days</td>
<td>Typical Factory, Accident</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>Cigarettes, Cardiovascular Disease, Cancer</td>
</tr>
<tr>
<td>500 cc</td>
<td>Wine, Cirrhosis</td>
</tr>
</tbody>
</table>
Anatomy of the Airway Space

- Nasal fossa
- Paranasal sinuses
- Nasopharynx
- Oropharynx
- Hypopharynx
Three Basic Views

Sagittal

Coronal

Axial Maxilla

Axial Mandible

Standard orthogonal planes and anatomical terms in the 3D volume
Nasal Fossa & Septum

- Nasal Septum
- Nasal Fossa

4 Functions
- Warms and humidifies the air
- Removes and traps pathogens
- Responsible for sense of smell
- Drains and clears the paranasal sinuses

Nasal Turbinates

- Superior concha
- Middle concha
- Inferior concha

Superior meatus
Middle meatus
Inferior meatus
Maxillary Sinus

Sinus inflammation

Periapical lesion
Maxillary sinus ostium

Lateral Pterygoid Plates

Medial Pterygoid Plates
Soft Palate

Nasopharyngeal Airspace
Oropharyngeal Air Space

Posterior pharyngeal wall
Hypopharynx

Hyoid Bone

Epiglottis
Airway Measured

Anatomical Variants and Pathologies
Concha Bullosa

- Pneumatization of the middle turbinate
- May cause narrowing of the middle meatus
- Considered a variation of normal

Paradoxical Curve of Middle Turbinate

- Convexity of the bone of the middle turbinate is directed laterally
- May narrow or obstruct the infundibulum or middle meatus
Deviated Nasal Septum

- Nasal spur and septal deviations
- May narrow or compress the middle turbinate laterally and the middle meatus

Diurnal Variation

- Normal cycle of alternating partial congestion and decongestion of the nasal cavity
- Don’t confuse with pathological nasal congestion
Hyperplasia of the Turbinate and Choana

- Nasal polyp obstructing the maxillary sinus ostium
- Usually benign soft tissue growths
- Appear tear drop or grape-like
- Result of chronic inflammation from asthma, recurring infection, allergies etc.
- Small polyps are not a problem
- Larger ones may cause blockage of the nasal passages and should be referred

Polypoid mass in the nasal fossa
• pseudocyst is caused by a blockage of the secretory ducts of the seromucous glands in the maxillary sinus which may cause accumulation of secretions between the layers of the maxillary sinus lining.
• It can be observed seasonally such as in early spring or fall.
• A mucocele is an expanding destructive lesion that may result from blockage of the ostium.
• Blockage results in the accumulation of secretions and an increase in the intra-antral pressure causing thinning, displacement and rarely destruction of the sinus wall.
• The entire sinus acts as a pathological entity.

• Antrochoanal polyp fills the sinus
• Enlarged ostium with extension into the middle meatus and nasal cavity
• Refer to ENT
Mucosal thickening

- 1-3 mm of mucosal thickening is considered normal

Acute Sinusitis

- Acute Sinusitis
  - Bubbly secretions indicate activity
  - No thickening or sclerosis of the cortical bone
Acute Sinusitis

- Note the bony erosion of the posterior cortical border
- May extend through the posterior sinus wall into the retroantral fat pad

Acute Sinusitis – Pediatric case
When to Refer???

Pan Sinusitis
Chronic Sinusitis

- Chronic sinusitis
- Thick and sclerotic cortical borders
- Opacification of the sinus
- Central radiopacity may be due to dystrophic calcifications or a fungal infection
- Note history of previous surgery

Acute exacerbation of a chronic sinusitis

- Bubbly secretions indicate activity
- Thickened and sclerotic cortical bone indicate long standing inflammation
Silent Sinus Syndrome

- Silent Sinus Syndrome
  - Chronic obstruction of the sinus
  - Chronic hypoventilation
  - Longstanding stagnant secretions
  - Thinning and remodeling of the sinus walls
  - Negative intrasinus pressure
  - Decreased volume of the maxillary sinus
  - Inferior retraction of the orbital floor (enophthalmos)
  - Refer to ENT
Dental Material in the Sinuses

Mucosal thickening of odontogenic origin
Antroliths

- Etiology: deposition of mineral salts such as calcium phosphate, calcium carbonate, and magnesium around a nidus
- introduced into the sinus (extrinsic)
- intrinsic such as masses of stagnant or inspissated mucous or cellular debris in sites of previous inflammation.
- The nidus for an antrolith is usually endogenous (root tip, bone fragment, blood clot, inspissated mucus, etc.).

Hypertrophic Adenoids
Tornwaldt’s cyst (also spelled Thornwaldt’s cyst)

Tonsilloliths
Acute Bacterial Tonsillitis

Lingual Tonsils

Research shows that lingual tonsil tissues > 2.7 mm was not identified in patients without obstructive sleep apnea-hypopnea syndrome or laryngopharyngeal reflux.

Michael Friedman, MD et al, Measurements of adult lingual tonsil tissue in health and disease, Otolaryngology-Head and Neck Surgery (2010) 142, 521-525
Nasopharyngeal Carcinoma

Esthesioneuroblastoma
Squamous Cell Carcinoma: Base of Tongue and Vallecula

Growth and Development

- Growth of mandible
- Skeletal Classifications
Growth over time

- Vector of overall growth is downward and forward

Growth of the Mandible

- Bony remodeling
  - Apposition is on the anterior aspect of the mandible
  - Deposition is on the posterior aspect of the mandible
  - Constant growth rate prior to puberty
    - 2-3mm/year in body length
    - 1-2mm/year in ramus height
Growth of the Condyle

Mandibular rotation patterns

“Long face” growth pattern

Normal growth pattern

“Short face” growth pattern
Airway and Skeletal Classifications

Class II  Class I  Class III

Treatment for OSA

- CPAP
- Surgery - Uvulopalatopharyngoplasty
- Orthognathic Surgery
- Oral Appliances
- Radiofrequency Ablation
- Lose weight
- Chin wrap
- Therapy
- Nothing
Example Cases: Orthognathic surgery

Class II

Pre-surgery

Post BSSO with genioplasty

Example Cases: Orthognathic surgery

Class II

Pre-surgery

Post BSSO with Lefort I
Example Cases: Orthognathic surgery
Class III

Pre-surgery
Post Maxillary Advancement

Pre-surgery
Post Maxillary Advancement
Example Cases: Orthognathic surgery

Class III

Pre-surgery

Post BSSO and Lefort I

Example Cases: Oral Appliances

No Appliance

Appliance

Case Courtesy of Dr. Tarun Argawal
Example Cases: Oral Appliances

No Appliance

Appliance

Case Courtesy of Dr. Tarun Argawal

Example Cases: Oral Appliances

No Appliance

Appliance

Case Courtesy of Dr. Tarun Argawal
Example Cases: Oral Appliances

No Appliance

Appliance

Case Courtesy of Dr. Tarun Argawal

OSA and TMD

- 1. OPPERA Cohort, n=2,604
- 2. Case control study, n=1,716
- Adults aged 18 to 44
- High likelihood of OSA:
  - Reported a history of sleep apnea
  - ≥ 2 hallmark features of OSA: loud snoring, daytime sleepiness, witnessed apnea and hypertension
- 248 of the cohort developed first onset TMD during the 2.8 year follow-up
- Conclusion “Both studies supported a significant association of OSA symptoms and TMD, with prospective cohort evidence finding that OSA symptoms preceded first onset TMD”

A.E. Sanders et al., Sleep Apnea Symptoms and Risk of Temporomandibular Disorder: OPPERA Cohort, JDR Clinical Research Supplement, July 2013
Temporomandibular Joint Disorder (TMD):

- Pain and dysfunction of muscles and osseous structures
  - Restricted jaw motion
  - Painful popping and clicking
  - Change in occlusion
  - Headaches
- Decreased quality of life
- Can become chronic
- Etiology: Trauma, orthognathic surgery, parafunctional habits, age, chronic inflammatory disorders
  - Poorly understood

Societal impact of TMD

- Common -1/3rd of adults and adolescents have signs/symptoms of temporomandibular disorders (1,2)
- Loss of approximately 17,800,000 collective workdays in the United States (3)

- TMD in children and adolescents (4, 5):
  - Mixed dentition study 25.7% had popping sounds and 9.6% had clicking sounds.
  - Reduced posterior facial height in orthodontic patients

- Osseous condylar resorption post-orthognathic surgery
  - Clinical effects - decrease in airway size and anterior open bite

References:
TMD Diagnosis

- Complex and varied
- Diagnosis and treatment planning is difficult
  - prolonged confusion and pain among patients

- Role of diagnostic imaging:
  - evaluating hard and soft tissues
  - confirming the extent or stage of disease
  - evaluate the effects of treatment
  - not every patient will require imaging

Articular Eminence
Quantification of condylar changes:
- Diagnose changes
- Evaluate Treatment

Stages of disease progression
Overlays and Absolute Distance
Color Maps

Overlays: Segmentation and actual condyle
TMD Classification

- Research Diagnostic Criteria for TMD (RDC/TMD)
- Clinical examination
- Radiographic examination

Publication Overview

- Multisite Research Diagnostic Criteria for TMD Validation Project
  - University at Buffalo, New York
  - University of Washington
  - University of Minnesota

- Evaluated interpretation reliability of CT, MR and Panoramic radiography

- Interpretation criteria developed from a literature review, NIDCR recommendations, and radiology/TMD community recommendations

- 724 Participants, 1448 Joints
Can Review Condyles with Cone Beam CT and 3D Models

<table>
<thead>
<tr>
<th>Osseous Classification</th>
<th>Classic Ahmad's</th>
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<tbody>
<tr>
<td>A.) No Osteoarthritic changes/ variation of normal</td>
<td>Normal relative condylar head size, No subcortical sclerosis or articular surface flattening, No deformation from subcortical cysts, surface erosion, osteophyte or generalized sclerosis</td>
</tr>
<tr>
<td>B.) Indeterminate/ adaptive remodeling</td>
<td>Normal relative condylar head size, Subcortical sclerosis with or without flattening, Articular surface flattening with or without subcortical sclerosis, No deformation from subcortical cysts, surface erosion, osteophyte or generalized sclerosis</td>
</tr>
<tr>
<td>C.) Osteoarthritic changes</td>
<td>Deformation Due to subcortical cysts, surface erosion, osteophyte or generalized sclerosis</td>
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</tbody>
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<table>
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<tr>
<th>Osseous Classification</th>
<th>Modified Ahmad’s</th>
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<td>Normal relative condylar head size, No articular surface flattening, No deformation from surface erosion or osteophytes</td>
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</table>

Studies with Dry Mandibles
Examples of Erosion and Flattening

Erosions

Flattening

PATHOLOGY

An example using CBCT for mandibular reconstruction after a resection of an ameloblastoma
3D reconstruction for modeling – TactileMed

Actual model
Pre-bent plate (Synthes)

Reconstruction
Digital Oral and Maxillofacial Surgery

- Surgical treatment planning
- Surgical predictions
- Fabrications of surgical stents
- Post surgical follow-up

Clinical uses for segmentation: The Virtual Patient

SICAT Function
Segmentation from a patient’s CT scan could be used to print out a patient specific anatomical scaffold and then use stem cells to generate vasculature and bone (1,2).

“Andreas Herrmann of the University of Groningen in the Netherlands and his colleagues have developed an antimicrobial plastic, allowing them to 3D print teeth that also kill bacteria.” NewScientist.com